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Preheat Effects on Shock Propagation in Indirect-Drive ICF Ablator Materials

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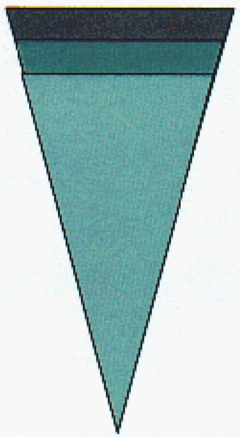
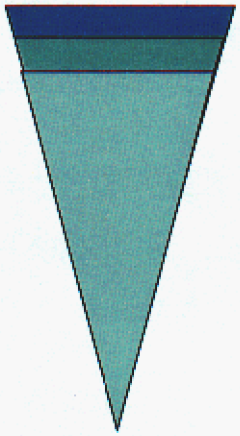
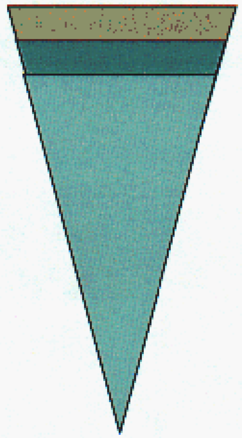
Cu-doped Be, Ge-doped CH, and polyimide are being considered as indirect drive ignition capsule ablators.







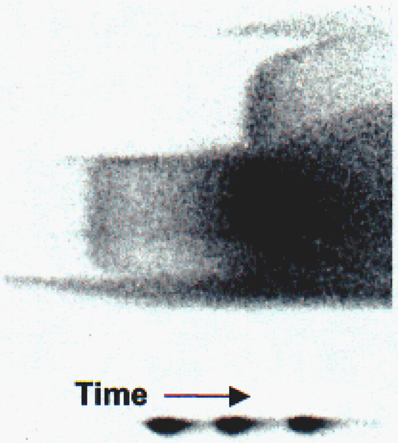
LANL Design:
D. C. Wilson, P. A. Bradley, et al., *Fusion Tech.*, 38, 16 (2000).
R. W. Margevicius, et al., *Fusion Tech.*, 35, 106 (1999).

[1]**LLNL and** [2]**CEA Designs**:
S. W. Haan, T. R. Dittrich, et al., *Fusion Tech.*, 41, 164 (2002).
A. Nikroo, et al., *Fusion Tech.*, 38, 58 (2000).
Ph. Baclet, et al., TFS Proc. (2003).

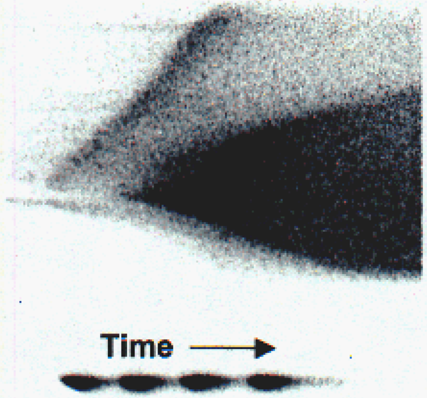
LLNL Design:
T. R. Dittrich, S. W. Haan, et al., *Fusion Tech.*, 31, 402 (1997).
C. Roberts, et al., *Fusion Tech.*, 38, 94 (2000).

A Streaked Optical Pyrometer (SOP) views the UV emission when the shock breaks out at the ablator sample surface .

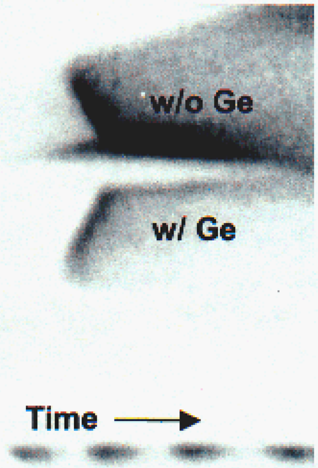
Be + 0.9% Cu Step



Be + 0.9% Cu Wedge ablator



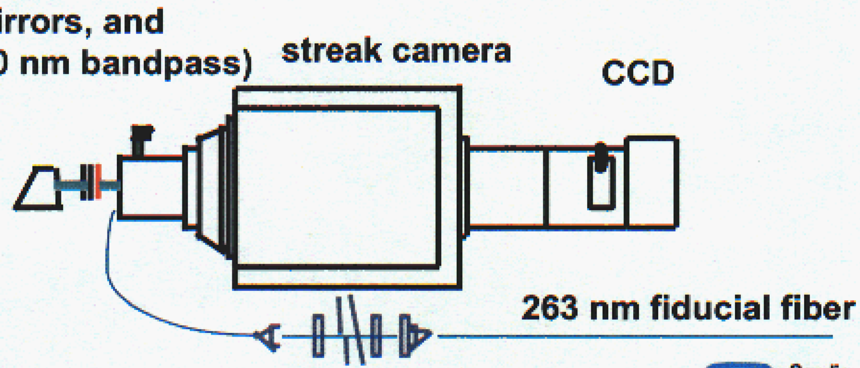
$C_{38}H_{60}O_2$ & $C_{39}H_{57}O_2Ge_2$ Wedges



Omega halfraum

step or wedge ablator sample

LANL Streaked Optical Pyrometer[1] (SOP)



[1]J. A. Oertel, et al, *Rev. Sci. Instrum.*, 70, 803 (1999).

Los Alamos
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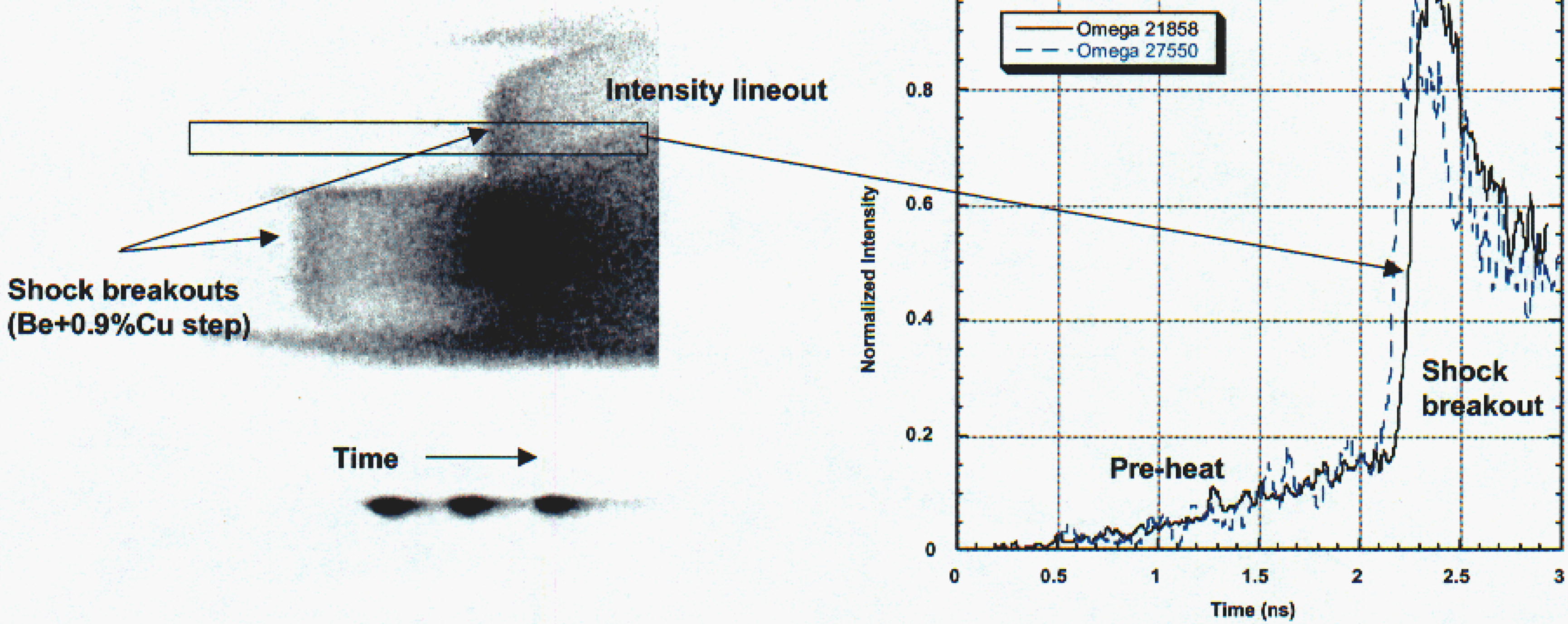
Features related to shock breakout, shock temperature, and pre-heat temperature are evident in the streaked SOP data.

TIM-5 SOP
Omega shot 21858

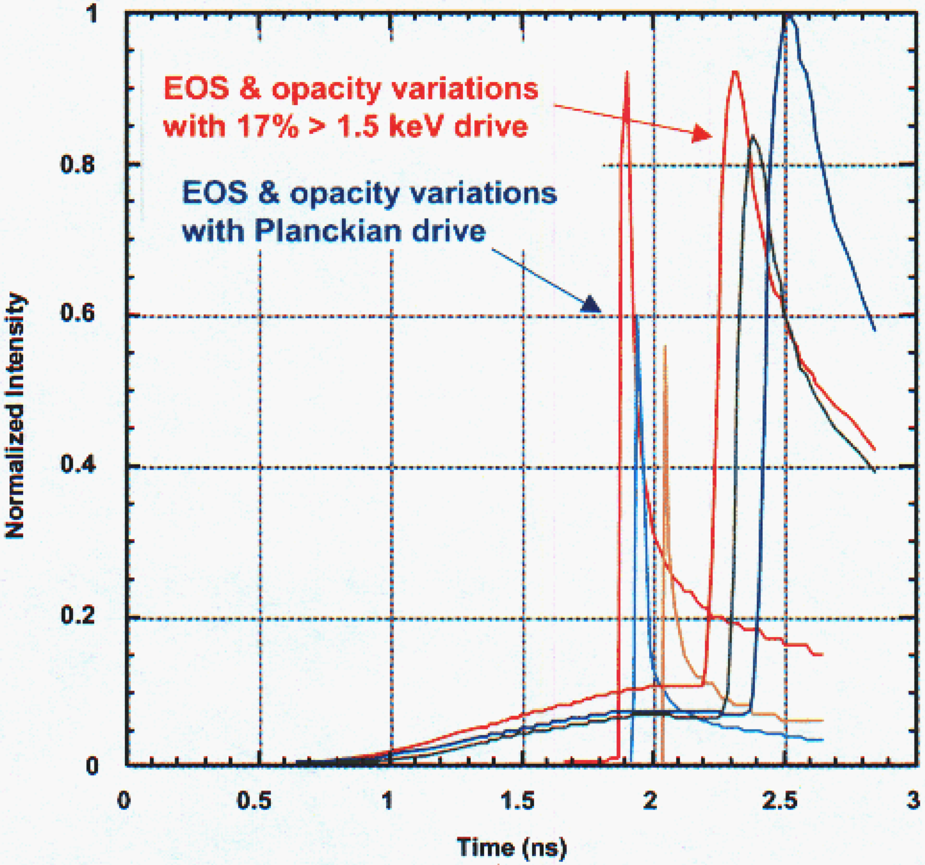
Lineout comparison:
Omega shots 21858 & 27550



The timing and intensity characteristics of the shock breakout and preheat features are repeatable on a shot-to-shot basis.

Spectral details are very important for the accurate calculation of shock timing and preheat in Cu-doped Be ablators. Opacity and EOS calculations appear to be of lesser significance.

Variations on a Be+0.9%Cu shock breakout calculation



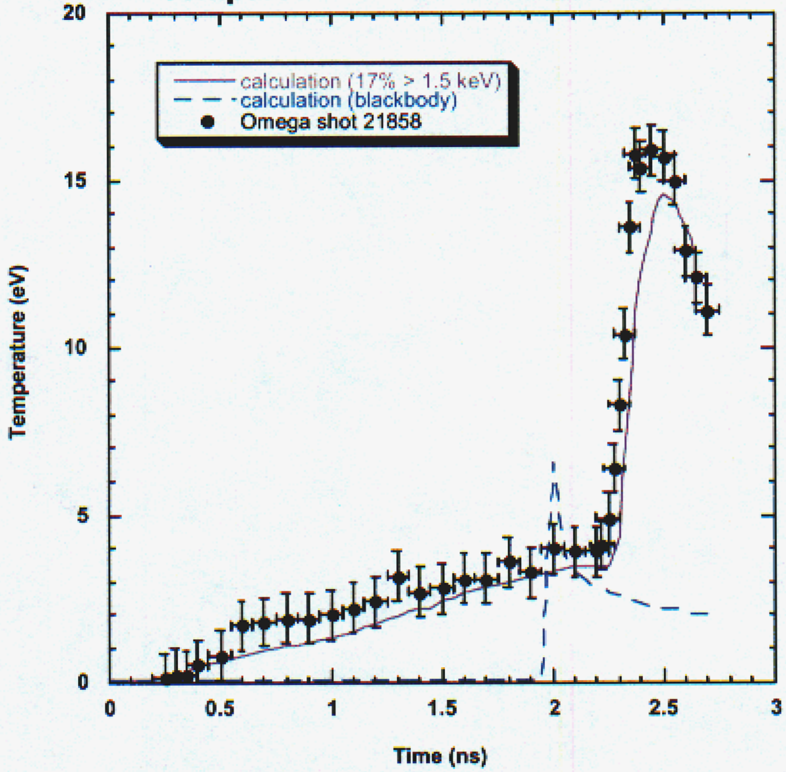
Shock breakout time and temperature and pre-heat temperature can be determined from the streaked UV image and compared to calculations.

	> 1.5 keV	time	pre-heat	shock
Tr calc	0.57%	1.9 ns	0.07 eV	8.0 eV
"NIF eq"	6.1%	2.2 ns	0.75 eV	12 eV
Exp calc	17%	2.5 ns	2.7 eV	16 eV
21858 data	--	2.4 ns	3.4 eV	15 eV
		+/- 0.1	+/- 0.2	+/- 0.8

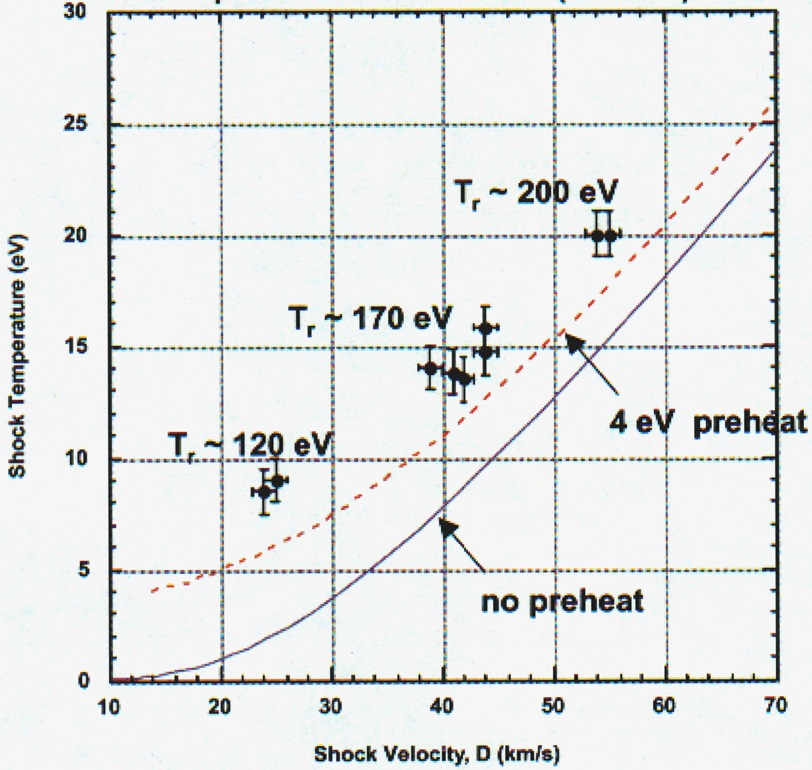
(Aluminum step data is used as a standard to unfold the temperature from the SOP intensity data.)

The x-ray preheat has a significant effect upon indirect-drive ICF ablator shock velocity and shock temperature.

Omega SOP data for Be (0.9%Cu) compared with Lasnex calculations

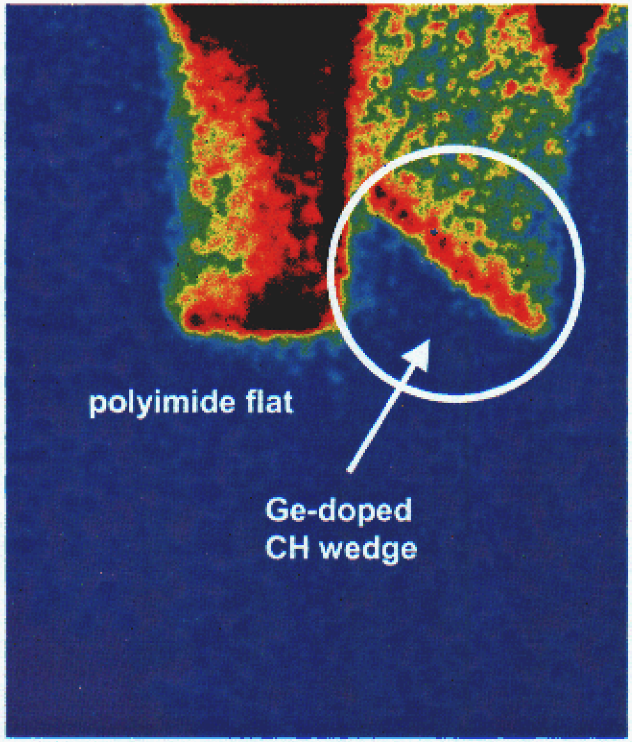


Sesame 2020 Be Hugoniot calculations compared with data for Be (0.9%Cu)



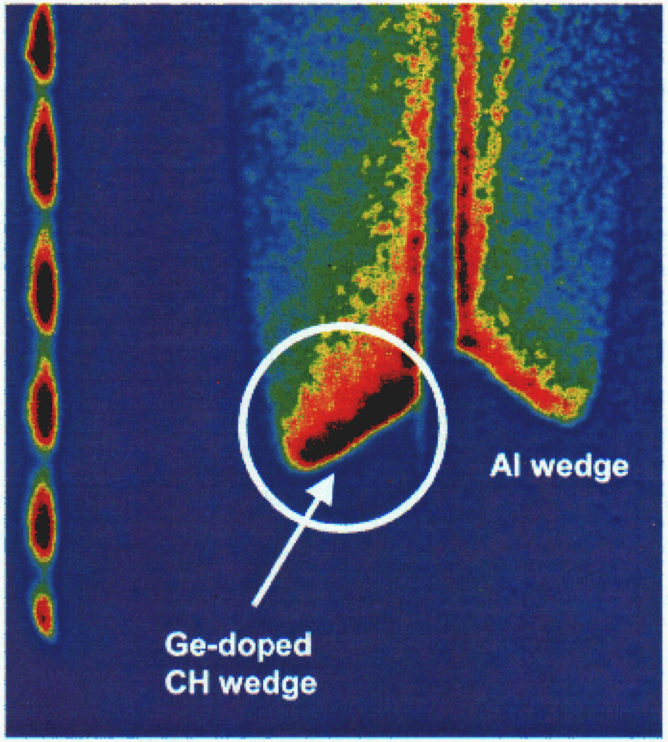
Multi-sample shock/preheat experiments provide side-by-side ablator comparisons or same-shot Al wedge drive measurement.

29911 SOP image (Dec., 2002)



flat and wedge samples:

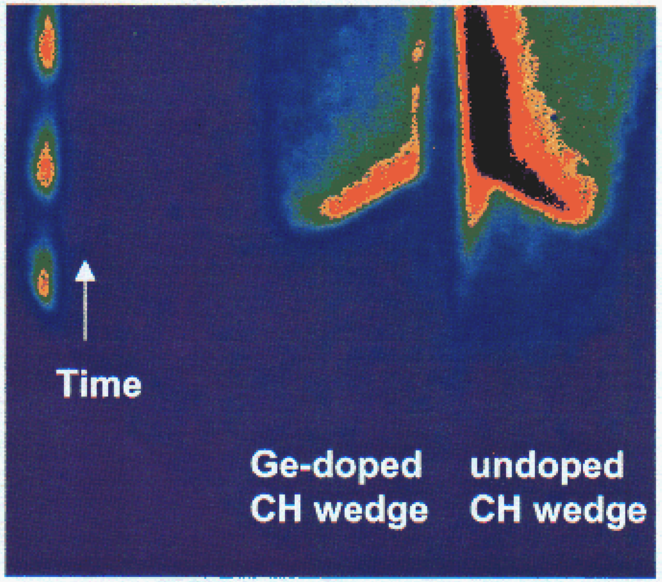
31820 SOP image (May, 2003)



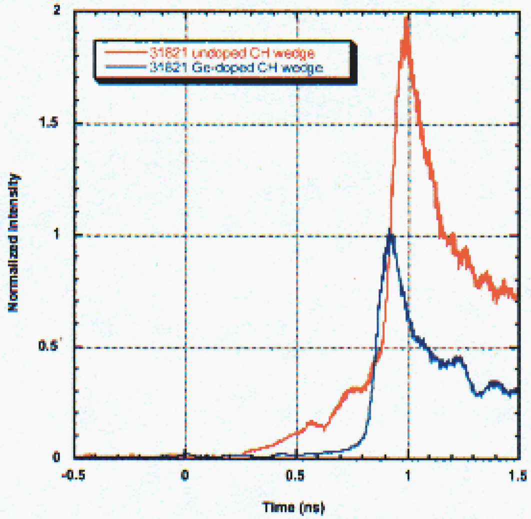
two wedge samples:

Side-by-side comparisons indicate that Ge dopant has a significant effect upon x-ray preheat level and shock temperature in CH ablators.

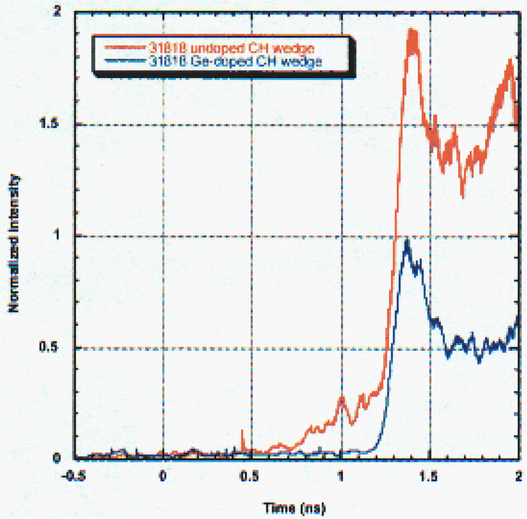
SOP image



CH/Ge & CH wedges
1 ns sq. laser pulse

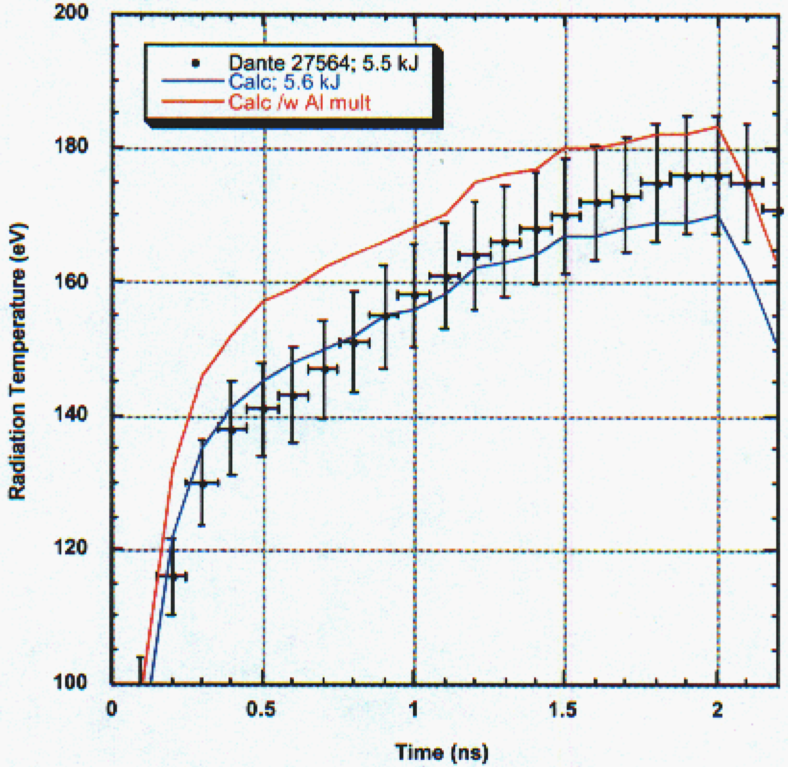


CH/Ge & CH wedges
2 ns sq. laser pulse

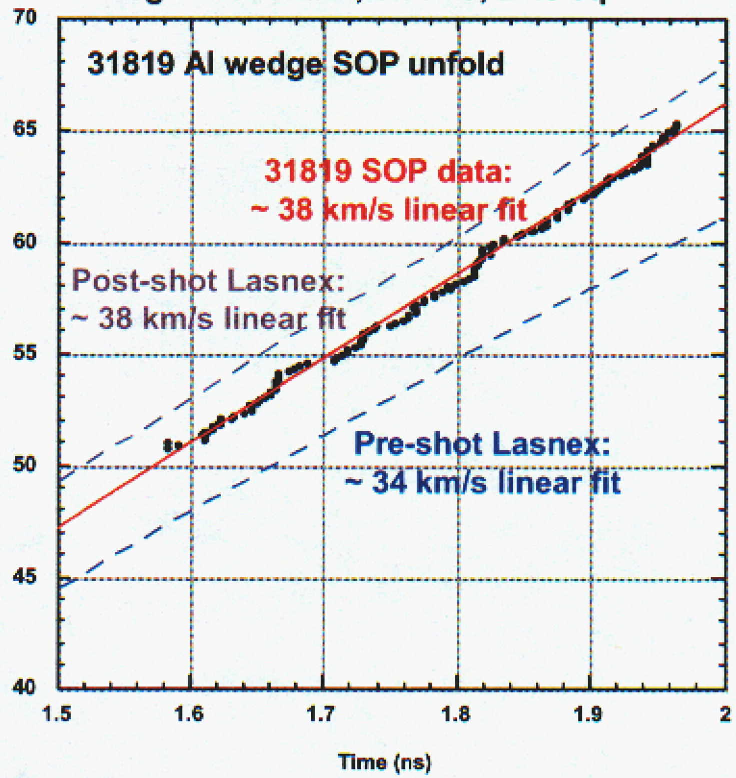


The ~ 8x reduction in preheat and ~ 2x reduction in shock temperature are approximately consistent with Lasnex calculations.

The Al wedge SOP measurements indicated higher velocities than predicted by 2D integrated Lasnex.



Omega shot 31819; 5.56 kJ, 2 ns sq



The ~ 38 km/s Al shock velocity can be explained with a drive multiplier.

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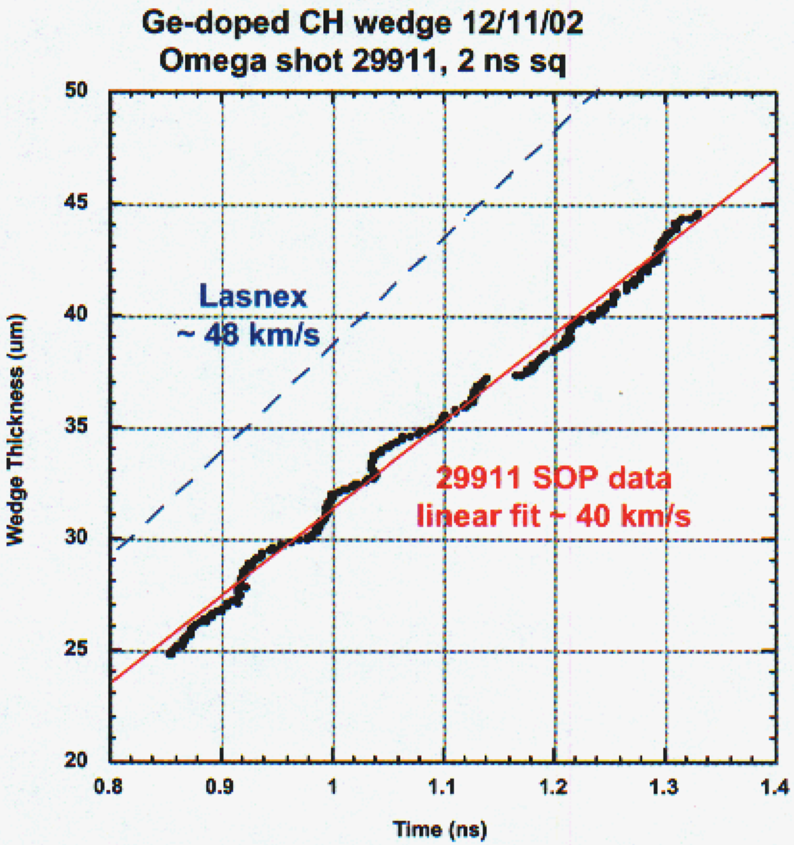
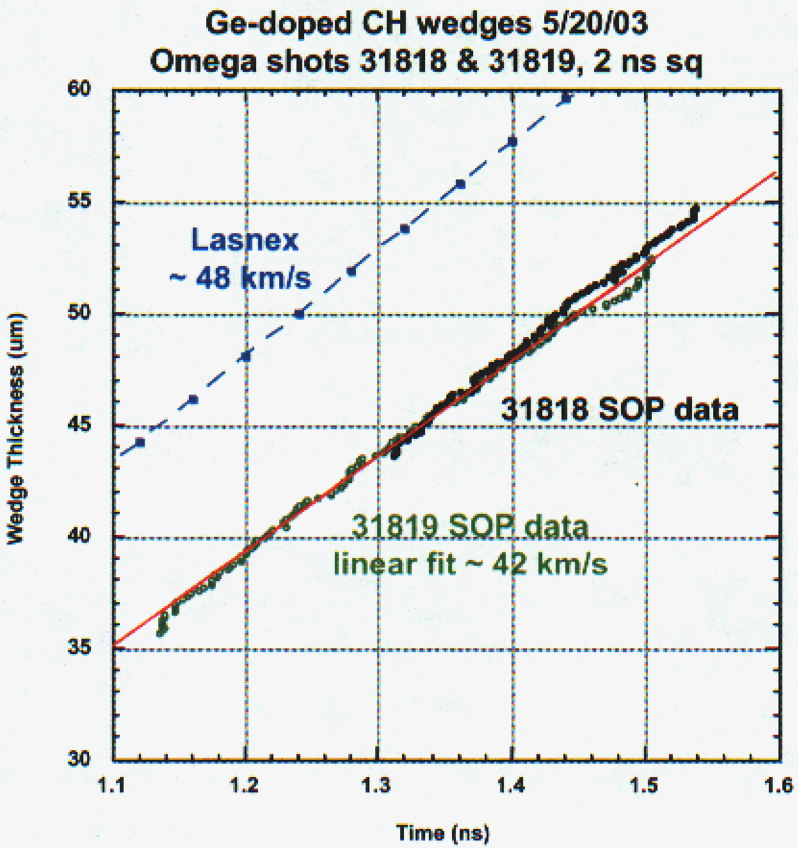
The Ge-doped CH shock velocity measurements have been ~ 12-15% lower than Lasnex calculations (2 ns sq).





Ge-doped CH shock velocities appear to be lower than Lasnex calculation, even though Al shock velocity is higher than Lasnex. This is also true for 1 ns sq experiments.

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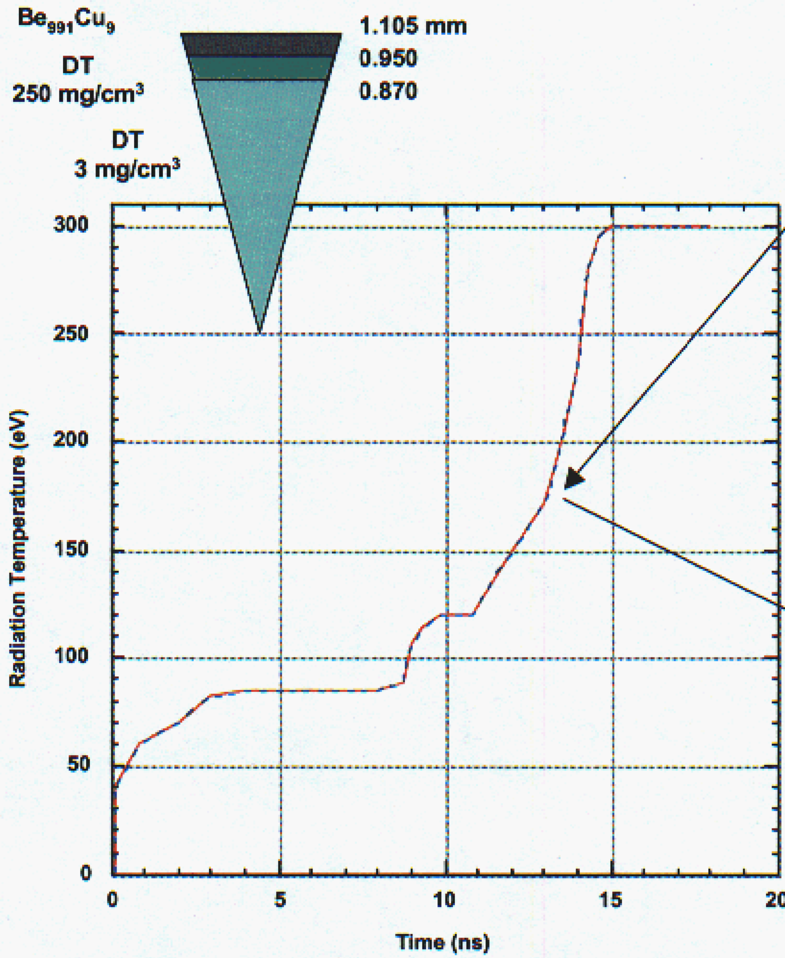
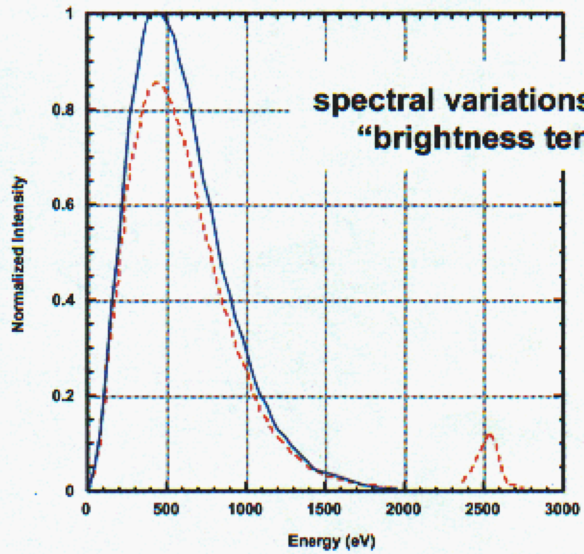
Variations on ignition capsule spectral input indicate that x-ray preheat can significantly alter capsule shock timing and yield.



at end of 3rd shock (~160 eV):

% flux > 1.5 keV	Yield (MJ)
1.6 %	18 MJ
6.1 %	16 MJ
15 %	5 MJ
22 %	0.1 MJ



Summary:

Omega experiments indicate that X-ray preheat ahead of an indirect-drive shock front causes significant shock propagation variations in Cu-doped beryllium, Ge-doped CH, and polyimide ablator samples.

We have experimentally demonstrated that dopants can be used to significantly alter (and perhaps control) the shock and preheat temperatures in x-ray driven ablator materials.

Ignition capsule sensitivity calculations indicate that drive spectra consistent with hohlraum albedo ~ 80-90% might result in significant yield degradation.

X-ray drive details in a full-size NIF ignition hohlraum will differ from the Omega situation, but this work indicates that an accurate understanding of ablator preheat will be essential for successful ignition of an indirect-drive capsule.

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